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THE SOURCE OF TOXICITY OF BACKWASH WATER FROM A SWIMMING POOL FILTER BED WASHINGS

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Abstract

The necessity of reducing the operating costs of swimming pools leads to attempts to reuse of backwash water from washing swimming pool filter beds. Their use for watering plants, sprinkling tennis courts and play fields, draining to nearby watercourses or even returning to swimming pool installations is taken into consideration. Current researches proved the toxicity of these waste streams. The results of these studies raise doubts about the rightness of the attempts to introduce washings from pool filters directly into the environment. The aim of the presented work is to determine the source of toxicity of filter backwash water. The assessed in the work washings were characterized by high turbidity, high content of both suspended solids and organic compounds. A decrease in value of general impurity indicators after the filtration process of washings has been shown, suggesting that the main source of toxicity may be the suspension, including various anthropogenic organic micropollutants. Although this is just a research hypothesis. For this reason, comparative studies on the occurrence of toxic organic micropollutants in raw filter backwash water, supernatant water and filtrate collected after the filtration process were carried out.

Keywords: **Filter backwash water; Micropollutants; Swimming pools; Toxicity; Water reuse.**

1. INTRODUCTION

The operation of swimming pools is very expensive thus investors are increasingly looking for solutions that can reduce these costs. Their particular attention is directed towards rational water and wastewater management. Huge losses of water are generated due to the necessity of regular washing of filtration beds in the pool water technological system. Extensive researches are carried out to check the possibility of reuse the filter backwash water (called also “washings”). The possibility of drainage this water stream to watercourses or into the ground is contemplated. It is also considered to reuse them for watering plants, sprinkling on tennis courts or playing fields or even for recycling to swimming pools [1-4]. In these studies, only the parameters which are included in the water law permit for the use of water and these specified by the Polish Regulation of the Minister of Environment regarding the conditions to be met to introduce sewage into waters or to the ground [5] are analyzed. Meanwhile, it turns out that washings from swimming pool filters may impact the selected indicators including a varied group of organisms: bacteria, crustaceans, insect larvae and vascular plants [6–9]. The toxicity effect differed depending on both the used type of biotest and the type of swimming pool from that the sample of filter backwash water was collected (Table 1).

Table 1.
The toxicity effect of filter backwash water on the various indicator organisms

Type of swimming pool from that the sample of filter backwash water was collected	Tested organism	Toxic effect [%]	References
School swimming pool	*Aliivibrio fischeri*	63	[6]
	Daphnia magna	40	
	Chaoborus falvicans	87	
Sports swimming pool	*Aliivibrio fischeri*	98	[7]
Hot tube	*Aliivibrio fischeri*	70	
Sports swimming pool	*Aliivibrio fischeri*	100	[8]
Jacuzzi	*Lemna minor*	31	[9]

The demonstrated toxicity of filter backwash water seems to be dangerous in the face of the fact that their discharge into rivers or soil is considered. The results of these studies raise doubts about the rightness of the attempts to introduce washings from pool filters directly into water or soil. In accordance with Directive 2006/11/EC [10], it is forbidden to introduce hazardous substances into the environment.

The aim of the presented work is to determine the source of toxicity of filter backwash water. As many micro-organic compounds has been found in swimming pool water [11–24], it is highly probable that some of them will be retained and accumulated on the filter beds and washed out of them during their washing. It is suspected that the potential presence of organic micropollutants in washings cause such a high toxic effect as described in previous works [6-9]. Even small concentrations of several ng/L of particular organic micropollutants may disturb the metabolic processes of numerous species of fauna and flora that have direct or indirect contact with them. Compounds whose primary impact is aimed at causing a specific effect on organisms which are in contact with them, seem to be particularly important in this field [25]. Such substances include pharmaceutical compounds, personal care products, pesticides and preservatives. Most of them are difficult to biode-

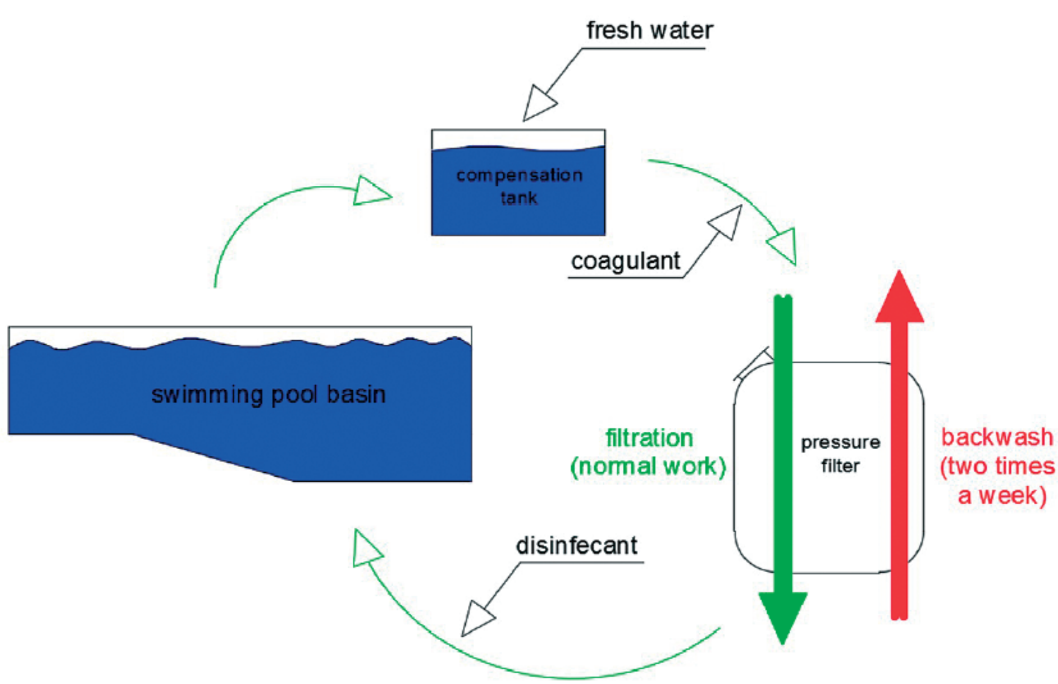

Figure 1.
The scheme of water treatment system in the tested swimming pool

Table 2.
Chronic toxicity of selected organic micropollutants in the water environment and their acute toxicity determined for aquatic organisms

Compound	The trophic group of tested organisms	Species of tested organism	Parameter (duration of the test)	The value [mg/L]	References
Ibuprofen	Vascular plants	*Lemna minor*	LOEC	22.00	[27]
	Crustaceans	*Gammarus pulex*	LOEC	0.00001	[28]
		Planorbis carnatus	LOEC	24.30	[29]
		Thamnocephalus platyurus	LC_{50} (24 h)	19.59	[30]
		Hydra attenuata	LC_{50} (96 h)	1.65	[31]
	Algae	*Desmodesmus subspicatus*	EC_{50} (72h)	315	[32]
		Synechocystis sp.	LOEC (72h)	1.00	[33]
	Molluscs	*Planorbis carnatus*	LC_{50} (72 h)	17.10	[29]
	Amphibians	*Xnopus laevis*	EC_{50}	30.70	[34]
	Fishes	*Oncorhynchus mykiss*	LOEC	1.00	[35]
		Oryzias latipes	LC_{50} (96 h)	>100.00	[36]
Caffeine	Rotifera	*Plationus patulus*	LC_{50} (48 h)	580.00	[37]
	Crustaceans	*Pimephales promelas*	LC_{50} (24 h)	100.00	[38]
	Fishes	*Chironomus dilutus*	LC_{50} (24 h)	1.23	[38]
		Pimephales promelas	LOEC	20.00	[38]
Carbamazepine	Vascular plants	*Lemna minor*	LOEC	22.50	[27]
		Lemna gibba	LOEC	>1.00	[39]
	Crustaceans	*Ceriodaphnia dubia*	LOEC	100.00	[40]
		Calluna vulgaris	EC_{50} (48 h)	155.00	[36]
		Ceriodaphnia dubia	EC_{50} (48 h)	77.70	[40]
		Hydra attenuata	EC_{50}	15.50	[31]
	Algae	*Desmodesmus subspicatus*	EC_{50} (72 h)	74.00	[27]
		Cyclotella meneghiniana	EC_{50} (96 h)	10.00	[40]
		Synechococcus leopolensis	EC_{50} (96 h)	17.00	[40]
	Insects	*Chironomus tentans*	LOEC	47.30	[41]
	Amphibians	*Xnopus laevis*	EC_{50} (96 h)	>100.00	[34]
	Fishes	*Oryzias latipes*	LOEC	6.10	[36]
			EC_{50} (48 h)	35.40	[30]
		Danio rerio	LOEC	50.00	[39]
		Oncorhynchus mykiss (juvenile)	LC_{50} (96 h)	19.90	[42]
Oxybenzone	Crustaceans	*Daphnia magna*	EC_{50} (24 h)	1.67	[43]
	Algae	*Scenedesmus vacuolatus*	IC_{50} (24 h)	0.36	[44]
		Desmodesmus subspicatus	IC_{50} (72 h)	0.61	[43]
	Fishes	*Oncorhynchus mykiss*	LOEC	0.75	[45]
		Oryzias latipes	LOEC	0.62	[45]

grade what increases their durability in the environment [26]. The presence of these groups of micropollutants in swimming pool water has been shown in mentioned researches [11-24]. The most commonly identified compounds in swimming pool water are: ibuprofen, caffeine, carbamazepine and oxybenzone (also known as benzophenone-3). Table 2, prepared on the basis of the paper [25], presents a review of literature data on both the evaluation of chronic toxicity for these micropollutants and their concentrations determined during the performance of acute toxicity tests of their aqueous solutions.

Table 3.
Water quality indicators evaluated for each tested liquid phase of washings

Parameter	Raw washings	Supernant water	Filtrate
pH [-]	9.15-9.58	8.94-9.58	9.05-9.25
Conductivity [mS/cm]	4.259-5.400	4.377-4.816	4.278-5.766
Potential redox [mV]	747-751	771-780	776-781
Absorbance UV_{254} [cm^{-1}]	1.826-2.760	1.028-1.160	0.885-1.132
Turbidity [NTU]	138-852	17.0-21.6	0.12-1.09
Content of suspensions [mg/L]	308-750	45-53	<25
TOC [mg/L]	66.28-70.65	56.33-59.38	57.32-61.2
TC [mg/L]	72.7-73.39	61.14-62.64	63.98-64.31
IC [mg/L]	2.05-7.11	1.76-6.31	2.78-6.99

2. RESEARCH METHODOLOGY

Filter backwash water for the research was sampled within one month from a swimming pool located in Upper Silesia, in Poland. In order to prepare a representative sample, the same volume of washings (the volume of each sample was 1 L) was taken five times during the rinsing process, in its various stages. Then all collected samples were mixed together. The representative sample prepared in this way was analyzed. It is considered in this paper as “raw washings”.

The washings were sampled from a pressure filter filled with two layers of bed (40 cm layer of sand with a grain diameter of 0.4–0.8 mm and a 60 cm layer of hydro-anthracite N with grain size 0.8–1.6 mm) supported by two layers of gravel with a grain size of 3–5 mm and 1-2 mm. The whole water treatment system used in a tested swimming is shown schematically in Figure 1. During backwash, the flow through the filter is reversed, i.e. the water flows under pressure from the bottom to the top of the filter. Filter backwash aims at: removal of accumulated pollution, loosening the filter material and preventing the abrasion of filter material. The tested filter is backwashed two times a week. It is done by means of the “air + water” method.

The analytical procedure was carried out in accordance with the following methodology:

1. Filtration and sedimentation of raw washings to divide the sample into a solid phase (sediment) and liquid phase (supersaturated water and filtrate).
2. Evaluation of selected water quality indicators, such as: pH, turbidity, redox potential, conductivity and TOC (total organic carbon) for each of water phases.
3. Extraction of micropollutants from each of water phases.
4. Quantitative and qualitative analysis using a GC-MS chromatograph.

The chromatographic analysis was carried out using the eluate from both the raw washings, the filtrate and the supernatant water. Micropollutants were extracted from each of liquid phases using the SPE method in columns filled with a non-polar adsorbent in the form of octadecylsilane (C18). Before extraction, the bed was conditioned with methanol and acetonitrile, and then washed with deionized water. The chromatographic analysis and the sample preparation were carried out in accordance with the developed analytical procedure presented in the paper [46]

3. RESULTS AND DISCUSSION

The tested filter backwash water was characterized by high turbidity, high content of both suspensions and organic compounds. The ranges of the obtained results of its quality parameters are presented in Table 3. The values of general impurity indicators were the worst for the raw washings. The sedimentation process made the supernant water quality indicators better. The greatest purity was obtained for the filtrate after the filtration process that allowed complete separation of the sediment and the liquid phase.

Chromatographic qualitative analyzes of raw filter backwash water allowed to obtain more than 200 different mass spectra. Based on them, 127 micropollutants have been identified with a probability of over 70%. The identification of micropollutants was carried out by interpreting the obtained mass spectra using the NIST 17 Mass Spectral Library. Among all of identified compounds, only 44 were previous tested for toxicity. Table 4 compares their presence in raw filter backwash water, supernatant water and filtrate. Basing on the data published in open chemistry database PubChem [47], 34 of these compounds are classified as potentially toxic.

Table 4.
The presence of micropollutants in individual liquid phases and their potential toxicity

Group	Compound	Raw sample*	Filtrate*	Supernatant water*	Potential toxicity**
Personal Care Products	Octanal	+	+	-	N
	Benzyl alcohol	+	+	+	Y
	Pentanedinitrile	+	+	+	Y
	Nonanal	+	+	-	Y
	Cyclohexasiloxane, dodecamethyl-	+	-	-	N
	Cetyl alcohol	+	-	-	Y
	Hexa-hydro-farnesol	+	-	-	Y
	Oleic Acid	+	-	+	N
	Diethyl Phthalate	+	+	+	Y
	Benzophenone	+	+	+	Y
	Isopropyl myristate	+	-	-	Y
	1-Octadecanol	+	+	+	N
	Octocrylene	+	-	-	Y
	Debrisoquine	+	-	+	Y
	Benzyl cyanide	+	+	-	Y
	Cimetidine	+	+	-	Y
	Undecylenic acid	+	+	-	Y
	Gitoxigenin	+	-	-	Y
Disinfection By-Products	2-Chlorohistidine	+	-	-	Y
	Decyl chloride	+	+	+	Y
	1-Tetradecanol, 14-chloro-	+	-	-	Y
	2,2,2-TriB-N,N-dimethylacetamide	+	+	-	Y
Industry additives	1-Eicosanol	+	-	-	Y
	Bis(2-ethylhexyl) phthalate	+	+	+	Y
	Kodaflex DOTP	+	+	+	Y
	Heptadecane	+	-	-	Y
	Hexadecanethiol	+	-	-	Y
	Dibutyl phthalate	+	+	+	Y
	Glycidyl oleate	+	+	+	Y
	Glycidyl phenyl ether	+	+	+	Y
	Nonanenitrile	+	+	+	Y
Food additives	Decanal	+	+	+	N
	Methyl caprate	+	-	-	Y
	Triacetin	+	+	+	N
	Methyl dodecanoate	+	+	+	Y
	Hedione	+	+	+	N
	Methyl tetradecanoate	+	+	+	N
	Tetradecanoic acid	+	+	-	Y
	Isopropyl palmitate	+	+	+	N
Cleaning Care Products	Dodecanenitrile	+	-	-	Y
	Palmitoleic acid	+	-	-	Y
	Methyl palmitate	+	+	+	N
	Dioctyl adipate	+	-	-	Y
	Tridecanoic acid	+	+	+	Y

*+present , - not present ; **Y-Yes, N-No

Among 34 of identified compound classified as potential toxic, 22 were also present in the filtrate and 17 in supernant water thus 13 were removed in the sedimentation and filtration processes what means they were contained in the sediment. 9 of them are classified as danger or warning in accordance with the GHS Hazard Statements. These are: cetyl alcohol, isopropyl myristate, octocrylene, gitoxigenin, heptadecane, hexadecanethiol, dodecanenitrile, palmitoleic acid, dioctyl adipate. Some of them (dodecanenitrile, hexadecanethiol, octocrylene, cetyl alcohol) are notified as very toxic and hazardous to aquatic life.

4. CONCLUSIONS

The decrease in the value of general impurity indicators after the filtration of washings suggests that the main source of toxicity may be suspension and sediment, including adsorbed toxic organic micro-pollutants. The compare of chromatographic qualitative analyzes for raw filter backwash water, supernatant water and filtrate partially confirms this conclusion. Almost 40% of the classified as potentially toxic compounds were removed in the sedimentation and filtration processes that indicates their content in sediment. However, it should be taken into account that there are no literature data on the toxicity of the most of the identified micropollutants. Therefore, the searching for the source of toxicity of filter backwash water should be extended to toxicological analysis of individual phases of washings and to the determination of the concentration of identified toxic substances. In addition, toxicity studies of particular identified compounds should be conducted. It should also be taken into account that the individual effects of toxicity may differ from the combined effects of toxicity in the mixture of various chemicals that occurs in the filter backwash water.

It was also concluded that the single sedimentation or filtration process used to clean the washings may not be enough before they can be reused.

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